Ocean Response Coastal Analysis System (ORCAS)

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LONG -TERM GOALS

Our long-term goal is to develop instrument systems for coherent, real-time monitoring of finescale biological, physical, chemical, and optical structure and processes within the ocean, in 3-dimensional space and time. These systems must be readily deployable, yet provide real-time data with sufficient vertical and horizontal resolution for determination of the coastal environmental response to episodic events such as storms, nutrient inputs, hypoxia and algal blooms.

OBJECTIVES

Our objective is to develop, test and demonstrate a system of autonomous bottom-up profilers that can be deployed in arrays to allow coherent assessment of changes in finescale biological, physical, chemical, and optical structure and processes in 3-dimensional space and time. These profilers also are designed to meet the needs of naval, environmental and basic research communities for self-contained, autonomous profiling systems that can be rapidly deployed in any coastal area of interest to test models and enhance the interpretation of data from other platforms such as remote sensing systems, AUVs and ship-based profilers. Our objectives during the first two years of the project were to design, develop and test the core technologies (underwater winches, micro-controllers, power systems, chemical analyzers, optical sensors, software, and communication systems) needed to build autonomous bottom-up profilers. Our objectives during the past year were (1) to incorporate these core technologies into self-contained autonomous profiler systems, (2) to tank test them as integrated systems, and (3) then deploy them in the coastal ocean to demonstrate their ability to meet the basic and applied needs of our Navy, EPA and university research partners.

APPROACH

Our approach is to use our long-term partnership with private industry (WET Labs, Philomath, OR and SubChem Systems, Jamestown, RI) and government labs (Dr. Alan Weidemann, NRL Stennis, MS. and Richard Greene, EPA Gulf Breeze, FL) to design, develop and test ORCAS. The ORCAS profiling system is based on a recently tested technology that used a small, semi-autonomous underwater winch

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14. ABSTRACT
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to deploy a CTD/optics package that profiled temperature, salinity, density, oxygen, spectral absorption and transmission at centimeter scales. Two types of ORCAS profilers are being developed under the current grant to meet the above objectives. The first is a small, light weight profiler that supports a limited number of physical, optical, and chemical sensors. This ‘mini-profiler” package is designed to be deployed in arrays to provide a 4-D picture of temporal and spatial changes in structure of the water column. The second is a “maxi-profiler” which will allow the bottom-up deployment of a more comprehensive suite of biological, physical, chemical, optical, and acoustical sensors designed to measure finescale structure and processes.

WORK COMPLETED

A mini-profiler has been designed, constructed and field tested in collaboration with our NOPP partners. The mini-profiler is a totally self-contained autonomous profiling system consisting of an underwater winch, a winch cable attached to a lightweight bottom anchor, a package controller with embedded GPS and spread spectrum radio, a 48-volt battery pack, a suite of state-of-the-art sensors, a data logger/controller, a light-weight frame to hold the components, a molded syntactic foam float to provide buoyancy, and a polycarbonate shield to reduce drag and protect the sensors. The mini-profiler collects data from the bottom-up by slowly reeling out the cable until it reaches the surface or a pre-set upper depth limit. Once at the surface, it transmits the data, receives new instructions, then returns to the bottom by rapidly reeling in the cable. The profiler is configured as a spar buoy to maximize vertical stability and simplify deployment and recovery. The mini-profilers are equipped with a core set of sensors that include a SeaBird SBE 49 CTD with imbedded pump and pressure sensor, a WET Labs ac-9 plus for measuring spectral absorption and attenuation at 9 wavelengths, flow sensors for the CTD and ac-9, and a set of sensors for measuring system performance. The mini-profilers can support a limited number of additional digital and analog sensors. The unit tested included a WET Labs chlorophyll a fluorometer, a WET Labs BB1 backscatter sensor (150° angle at 532 nm), an NRL bathyphotometer for measuring bioluminescence, and a SeaBird SBE 43 oxygen sensor. The profilers are equipped with an anti-fouling system that includes copper intake tubes for the flow-through optical sensors and a copper-backed shutter on the backscatter sensor. Based on the success of field tests, we have constructed 3 additional mini-profilers so we can test them as a 4-D system.

We have completed the development and initial field testing of the software needed for autonomous operation of the profilers, data storage and transmission, and near-real-time processing and display of the data. The software runs on portable PCs and includes a Windows GUI interface that gives the user considerable flexibility in setting up the profiler, transferring data, and subsequent data processing.

A prototype maxi-profiler has been designed and constructed. The maxi-profiler supports the same suite of sensors as the mini-profiler plus an autonomous nutrient analyzer that is being developed by SubChem Systems as part of this grant. The autonomous nutrient analyzer is currently being integrated into the maxi-profiler in preparation for initial field tests. The maxi-profiler also includes an additional digital data multiplexer so that other digital sensors can be added in the future.

Two successful field tests of the mini-profilers have been conducted in open coastal waters. In the first test we deployed a mini-profiler from the RV Pelican in 20 m of water in the Gulf of Mexico off Corpus Christi, TX. This deployment was made in close collaboration with ongoing tests of diver visibility/vulnerability models being conducted by Alan Weidemann (NRL), LCDR Kimberly Lunde (NAVOCEANO) and a team of Navy explosive ordinance divers (see separate ORCAS report by Weidemann and Lunde). The mini-profiler autonomously collected bottom-up profiles of inherent optical properties, bioluminescence, and physical structure every 30 minutes and radioed them to the ship after each profile. In the second test we deployed a mini-profiler from a small vessel in 22 m of water in northeastern Monterey Bay, CA. This deployment was made in close collaboration with D.V. Holliday (BAE Systems) and M.A. McManus (UCSC) as part of a joint ONR effort to test for thin layers in open coastal waters (see separate reports by Holliday, McManus and Donaghay). The mini-profiler autonomously collected bottom-up profiles of inherent optical properties, bioluminescence, and physical structure once an hour and radioed them to shore twice a day for a week. Optical data from this study is being prepared for submission to the WOODS optical data base.

RESULTS

We are very excited and encouraged by the results of our field tests with our Navy partners in the Gulf of Mexico. These tests demonstrated that these systems could be rapidly deployed to provide the optical data needed to predict diver visibility and vulnerability. The mini-profilers were able to provide this data under weather conditions that severely restricted our ability to collect similar data with a ship-deployed high resolution profiler. As a result, these tests represent an important step toward developing operational systems that could meet these needs. In addition to meeting the needs of our Navy partners, these tests provided the developers at WET Labs and URI with a set of engineering data on the performance of these systems during storms.

We are also very excited and encouraged by the results of our field tests in Monterey Bay. These tests demonstrated that the mini-profilers have developed to the point where they can be deployed in the coastal ocean to autonomously collect the time series of centimeter resolution optical profiles. Such profiles are needed to detect, fully resolve, and optically characterize finescale optical structures such as the thin layers and relate them to physical structure measured by the CTD. This test also demonstrated that the software has developed to the point where it could be used to process and visualize the data in near-real-time so that we could track the development and vertical position of the thin layer over time (Figure 1) and guide the collection of samples from inside and outside the layer. This combination of capabilities is essential to both basic research applications (such as testing models of thin layer dynamics and impacts), environmental applications (such as detecting and guiding sampling of harmful algal blooms that occur in thin layers), and Navy applications (such as diver visibility/vulnerability).

IMPACT/APPLICATIONS

The autonomous moored profilers and compact oceanographic sensors developed in this project have a broad range of scientific, technical, environmental, and defense related applications. Once developed, these systems should have a substantial impact on the way we observe ocean variability, and our understanding of the significant role that episodic events play in the dynamics of coastal environments. The developments this year represent a critical step forward toward our goal of developing sampling systems that dramatically reduce the under-sampling of vertical structure and the temporal-spatial confounding that is inherent with existing technologies in highly variable coastal systems. The developments this year also represent a major advance in making the data available in real-time so that it can be used to guide sampling, modeling, and making decisions in coastal waters.

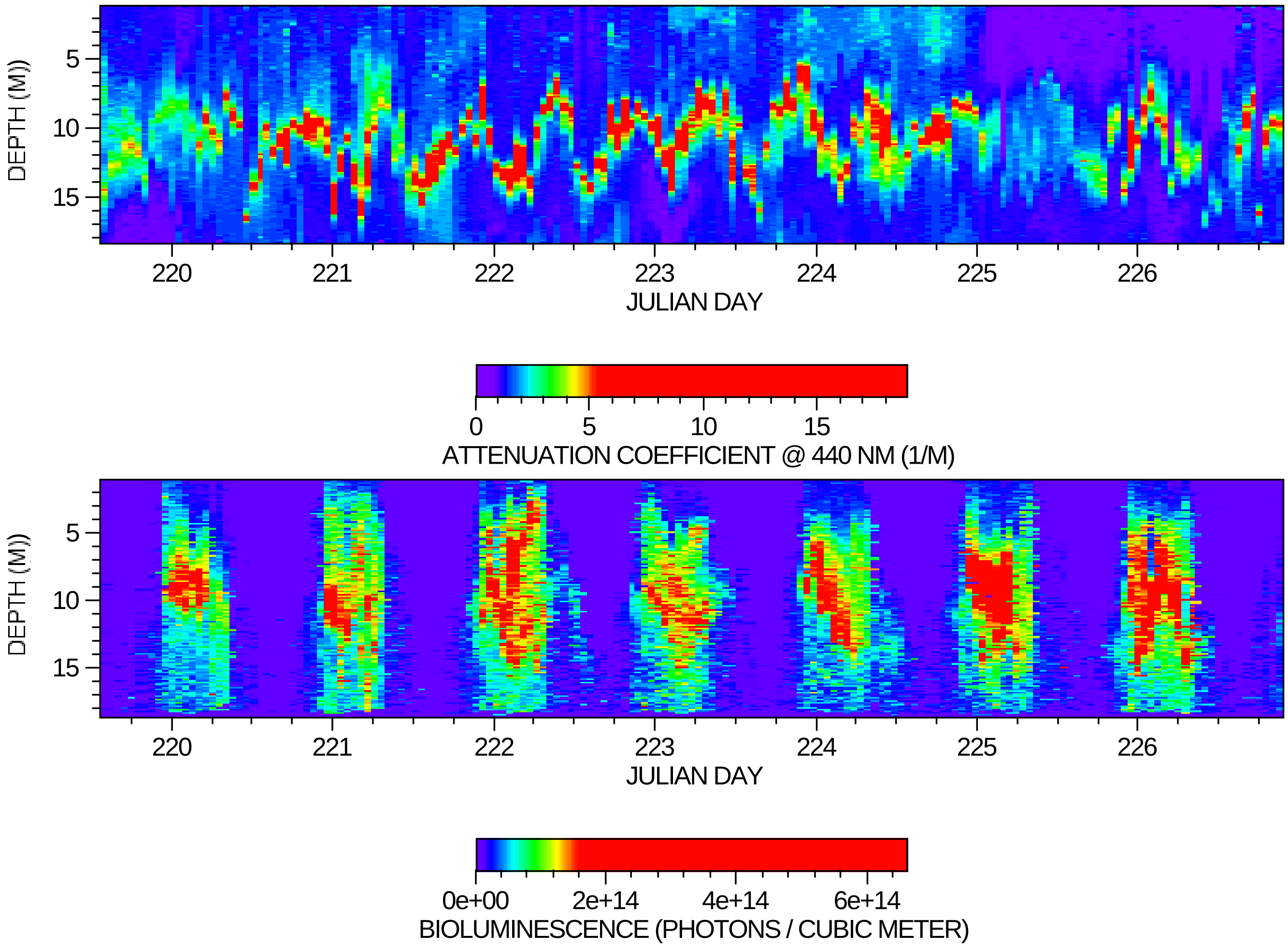

Figure 1. Temporal variation in the vertical optical structure over a week in Monterey Bay. These plots were generated with Spyglass Transform from the 178 hourly finescale vertical profiles collected by the mini-profiler. The top panel shows that the high attenuation coefficients associated with the development of the thin layer changed depth over time, but persisted for 5 days with intensities in excess of 5 m^{-1}. Maximum values in this layer reached extremely high values of 18 m^{-1}. The bottom panel shows that while bioluminescence was much higher during the night (as expected), it peaked in a thin layer that moved vertically during the night and tended to track the vertical movements of the thin layer seen in the attenuation coefficient data (top panel). These vertical movements in optical layers were dominated by changes in the depth of the thermocline (see report by Donaghay).

The sensors, micro-controllers, software, and underwater winches developed in this project have broad application beyond ORCAS. First, the new sensors are being incorporated into other types of platforms such as ship-deployed profilers, undulating towed bodies, and AUVs. For example, SubChem Systems has developed and is selling a cable-powered version of the nutrient analyzer (SubChen Pak analyzer) that can be towed behind a ship (the SubChem XZ Profiler) or used to collect vertical profiles from a ship. In addition, they are working with the Naval Underwater Weapons Center (NUWC in Newport, RI) to incorporate the autonomous nutrient analyzer into a REMUS AUV so it can be used to map chemical plumes. Second, the micro-controller/data handler technology developed for ORCAS is now being used by WET Labs in other platforms such as moorings, ship-deployed profilers, and undulating towed bodies. This technology should be easily adaptable to control the cabled profilers envisioned for long-term coastal observing systems. Third, the data processing software developed in this project is being made available to the optics and bio-optics community to facilitate collection and analyzes of data from a variety of existing optical profiling systems.

TRANSITIONS

This project has been specifically designed to rapidly transition the results of our research and technology development to users in the Navy, EPA, industry and oceanographic research communities. Our partnership with Alan Weidemann (NRL-Stennis) and LCDR Kimberly Lunde (Commander, Naval Meteorology and Oceanography Command) is specifically intended to insure rapid transition of the results to the Navy. During our two joint field tests we cross calibrated instruments, shared data, and had extensive discussions of how we could optimize the profilers to meet Navy needs. As part of this effort, we have provided them with copies of all of the physical and optical data collected by the ORCAS profilers and our ship deployed high resolution profiler. Our partnership with Richard Greene (Environmental Protection Agency Gulf Ecology Laboratory) is designed to insure transitioning to EPA and other users in the field of environmental assessment. Our partnership with Casey Moore and Ron Zaneveld (WET Labs) and Alfred Hanson (SubChem Systems) is designed to insure the development of instruments that will be commercially available to other groups. Participation by WET Labs engineers in the tank and field tests not only accelerated the development of ORCAS, but also gave them a much better appreciation of what was needed to transform the prototype profilers into reliable oceanographic instruments that could meet the needs of the diverse group of users.

RELATED PROJECTS

1. Alan Weidemann (NRL-Stennis) and LCDR Kimberly Lunde (Commander, Naval Meteorology and Oceanography Command): Separate funding for ORCAS.

2. Richard Greene (EPA-GED): Separate funding for ORCAS. Internal EPA-GED funding for investigations of (a) environmental factors regulating HAB growth dynamics, life cycles, and toxiciy, and (b) effects of zooplankton grazing and co-occurring bacteria on HAB dynamics.

3. ORCAS related efforts of WET Labs, SubChem Systems, and UCSC are funded via subcontracts of this grant and are reported herein.

4. Percy Donaghay (URI): ONR Biology and Chemical Oceanography Program funding for studies of the biological - biological, physical - biological and chemical - biological interactions that control the initiation, maintenance and dissipation of plankton patches.

5. D.V. Holliday (BAE Systems): ONR Biology and Chemical Oceanography Program funding to use acoustic techniques to quantify the occurrence, intensity and characteristics of thin zooplankton layers.

6. Margaret Dekshenieks (UCSC), Thomas Osborn (JHU), and Percy Donaghay (URI): ONR Physical Oceanography funding examining large scale physical forcing of thin layer dynamics.

7. Alfred Hanson (SubChem & URI): ONR Biology and Chemical Oceanography Program funding to measure the finescale nutrient structure associated with thin layers. NOAA funding to develop and

commercialize the XZ submersible chemical analyzers. DURIP and NUWC (Newport, RI) funding to add the autonomous nutrient analyzer to REMUS AUV and used it to track chemical plumes.

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